



Lunar Flashlight CubeSat GNC System Development for Lunar Exploration

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*With acknowledgements to the
entire Lunar Flashlight team*



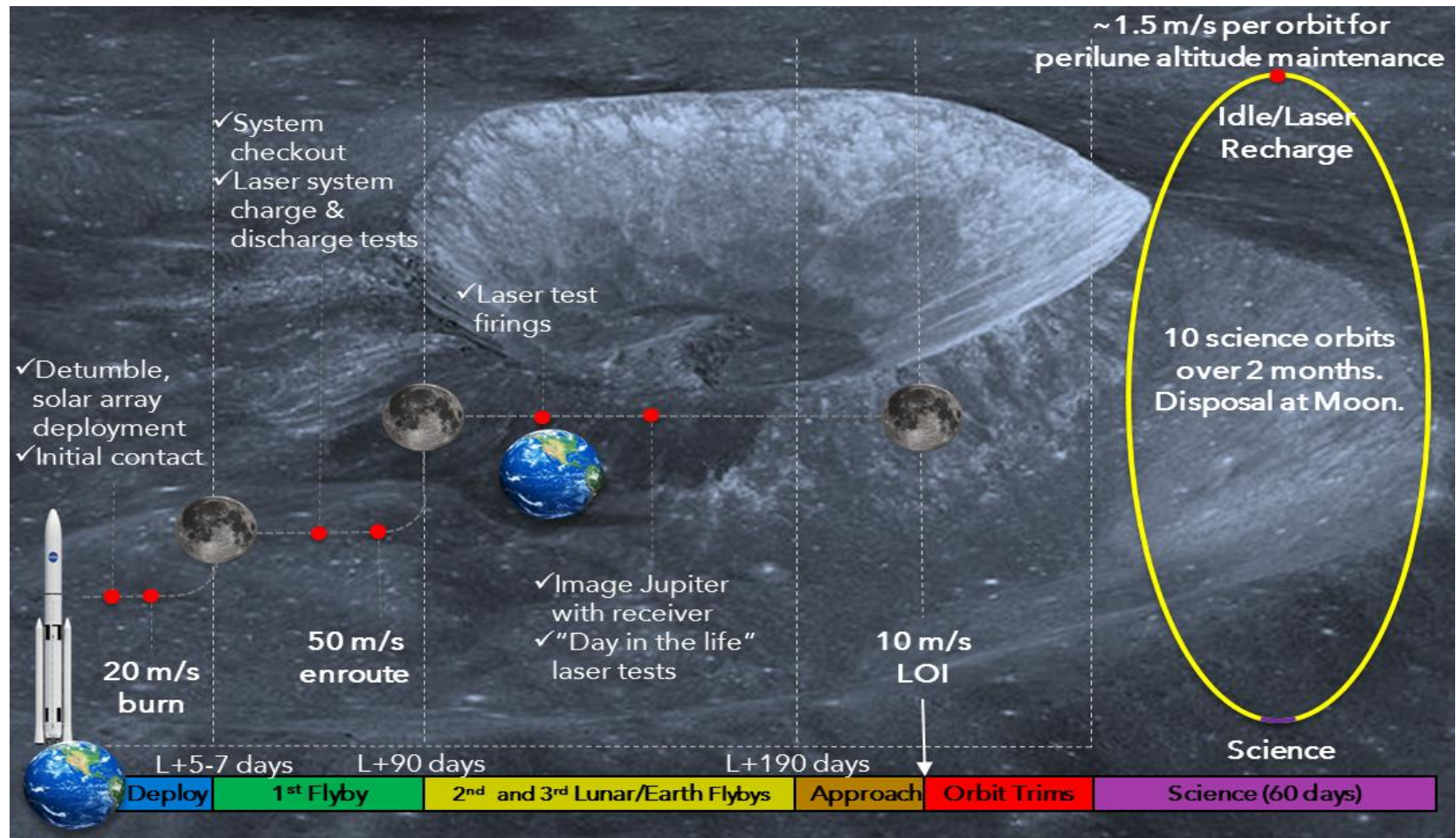
- ◆ **Mission Overview**
- ◆ **Capability Driven GNC System Development**
 - Early Stage: Solar Sail Approach
 - Major Design Change: Integrated GNC System w/ Chemical Propulsion
- ◆ **Technology Enhancement**
 - New Reaction Wheel
 - Green Propellant Thruster
 - On-board Ephemeris and Lunar Orbit design
- ◆ **Final GNC System**
 - Architecture and I/F with Propulsion and C&DH
 - Control Design Challenges
 - Fault Protection
- ◆ **Hardware Delivery and I&T**
 - Small Satellite Dynamics Testbed (SSDT)
 - Avionic Testbed (ATB)
- ◆ **Lessons Learned and Summary**



Mission Applications Overview



- ◆ Humans exploring the Moon would need water
- ◆ To detect surface ice deposits in south pole lunar cold traps
- ◆ 8-month mission, extendable to 18 months



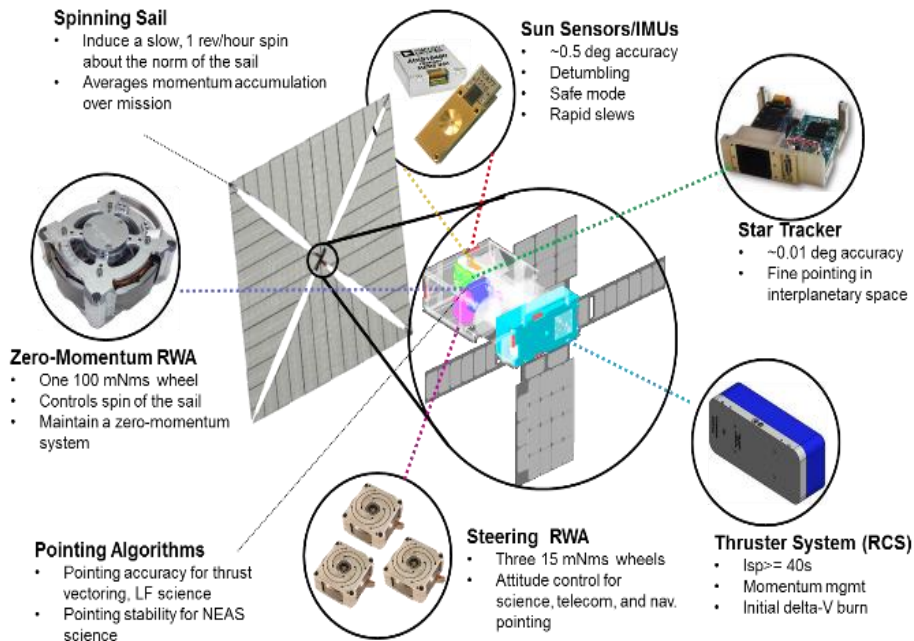


Capability Driven GNC System Development



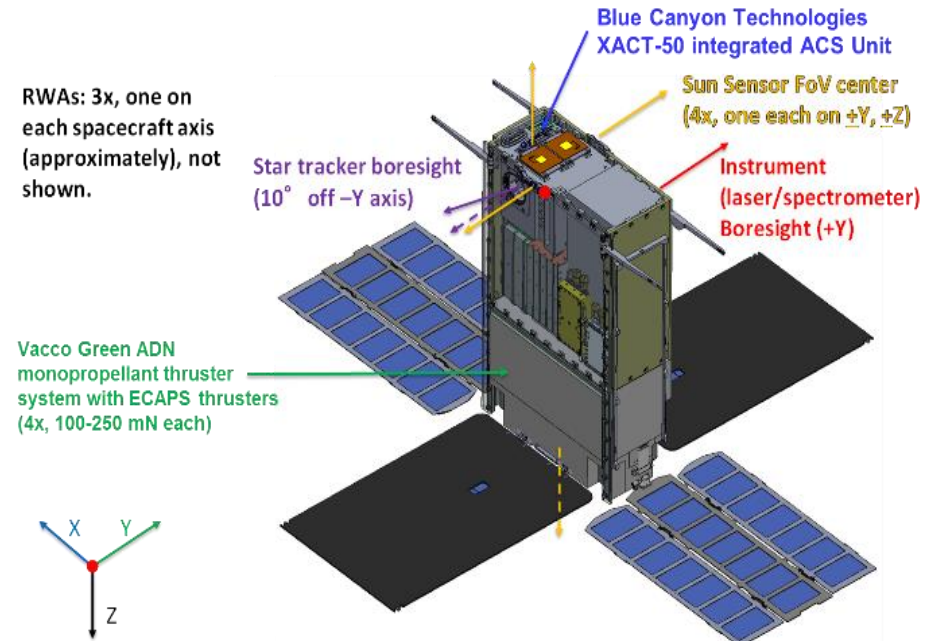
◆ Early Stage: Solar Sail

- Co-developed with NEA-Scout
- Sail -> prime propulsion
- Issue at Lunar Orbit Insertion (LOI) due to Earth gravity



◆ Major Re-design:

- Cost effective integrated GNC System
- Chemical propulsion ~100 m/s





◆ New Reaction Wheel

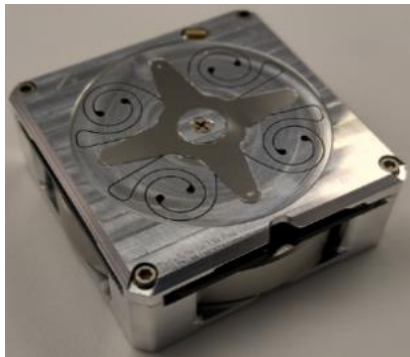
- Detumble from 10 deg/sec
- 15 mNm RWA -> 50 mNm by Blue Canyon Technology

◆ Green Propellant Propulsion (VACCO/ECAPS)

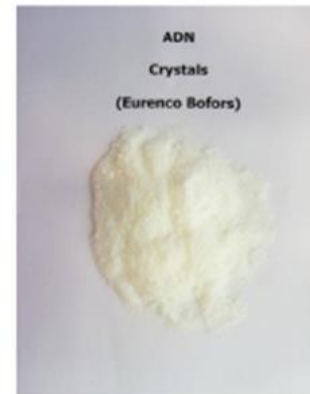
- 100 mN thruster
- Ammonium DiNitramide (ADN) based green propellant

◆ On-board ephemeris and Lunar orbit design

- Chebyshev polynomial based ephemeris
- Lunar near-rectilinear halo orbit (NRHO), perilune distance of ~15 km above the lunar south pole



ADN



LMP-103S



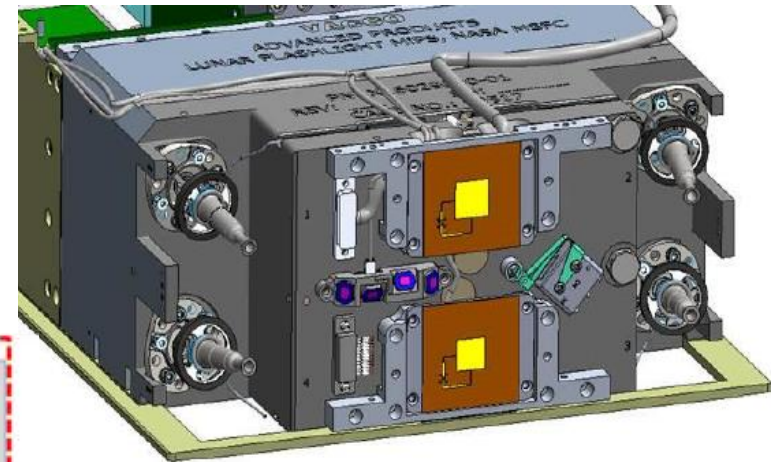
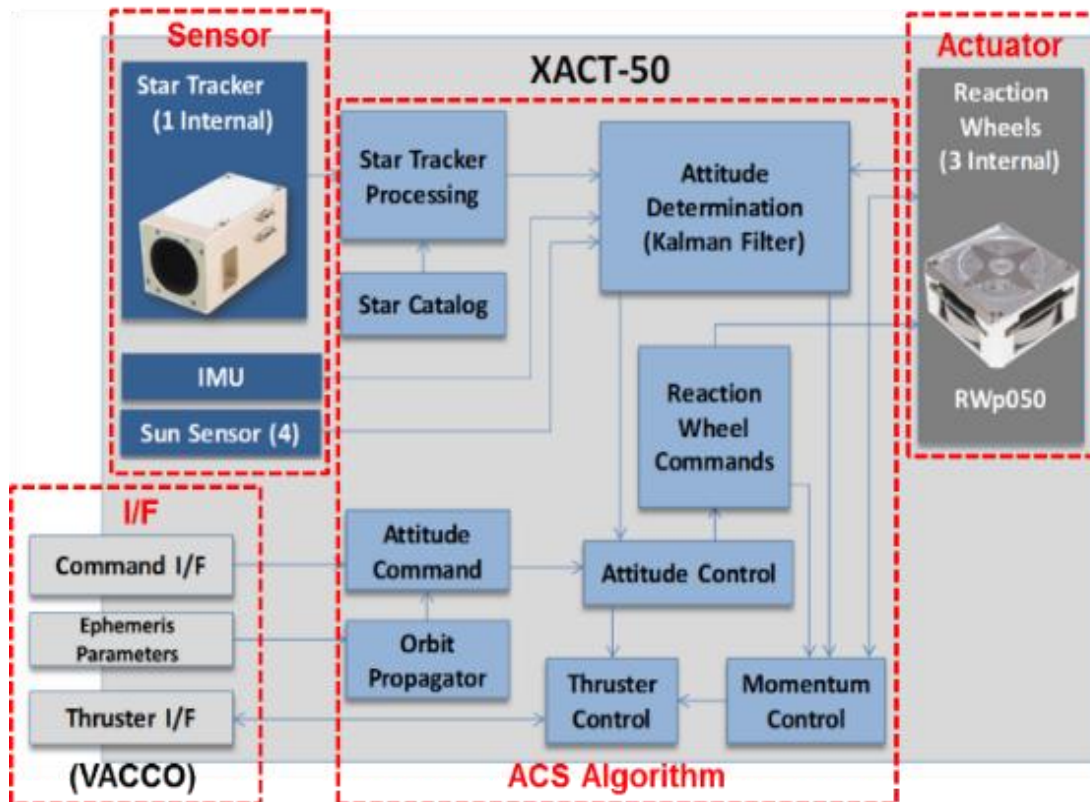


Final GNC System



◆ XACT-50 by BCT

- 1x SRU
- 1x IMU
- 4x Sun Sensors
- 3x RWAs (50 mNm)



◆ Propulsion by VACCO/ECAPS

- 4x thrusters (100 mN)
- Ammonium DiNitramide (ADN) based green propellant

◆ JPL C&DH

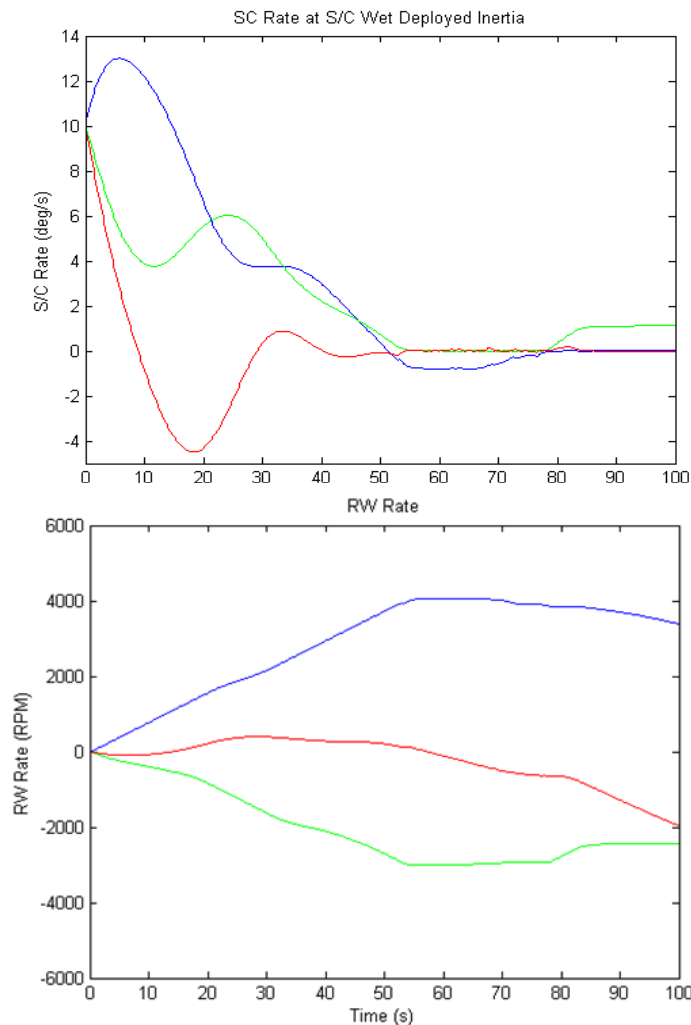
- SC flight computer to drive GNC, Propulsion, & other systems



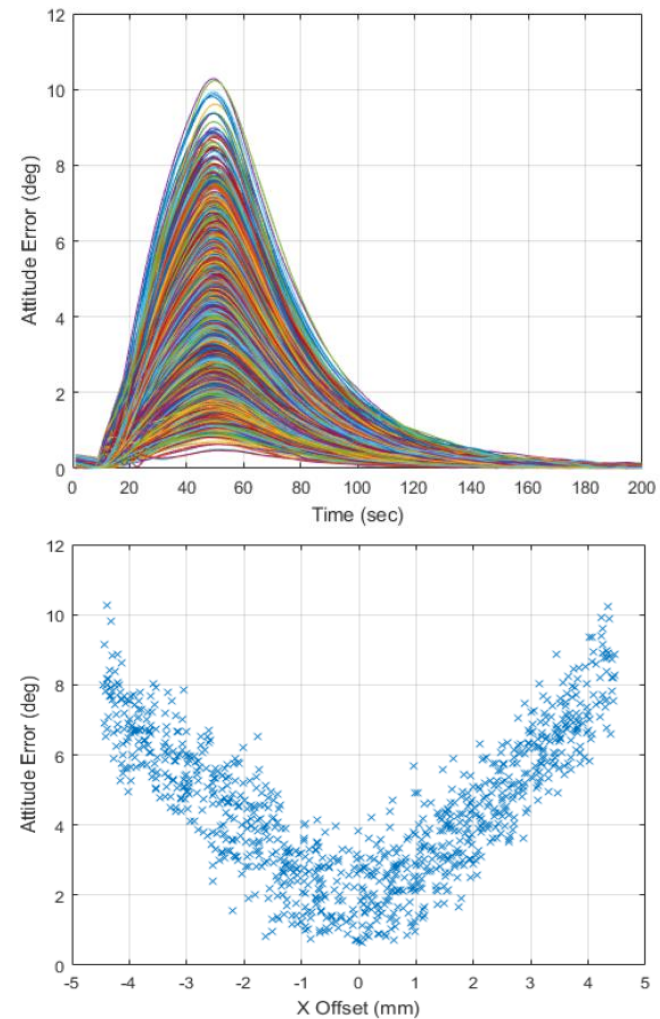
Design Challenges



◆ Detumble from 10 deg/sec by RWAs



◆ ΔV Transient Error & CM offset sensitivity

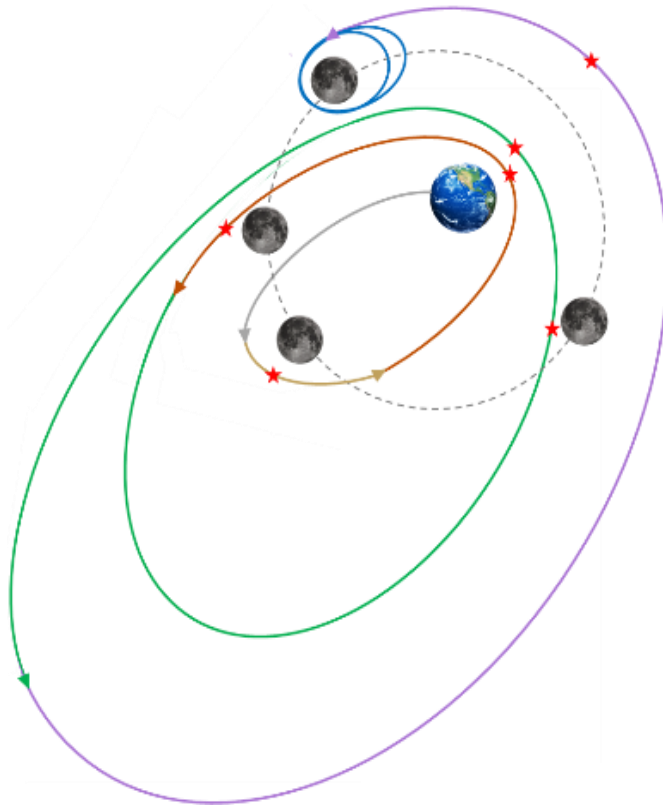




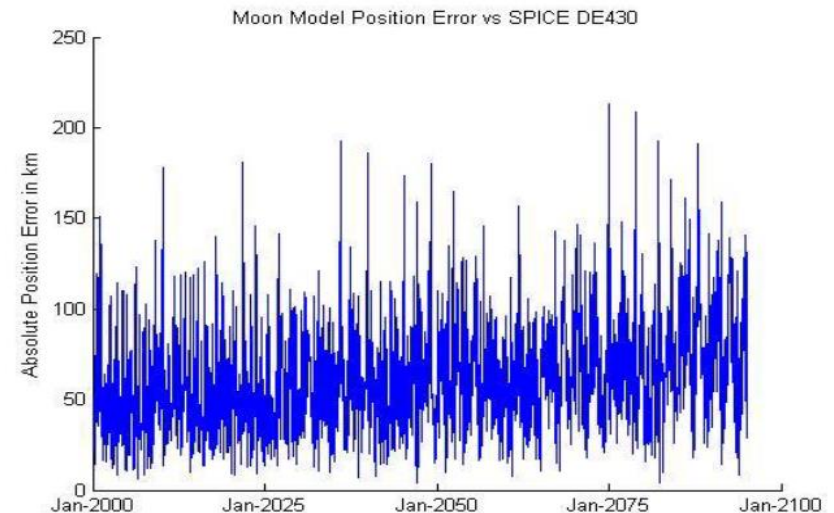
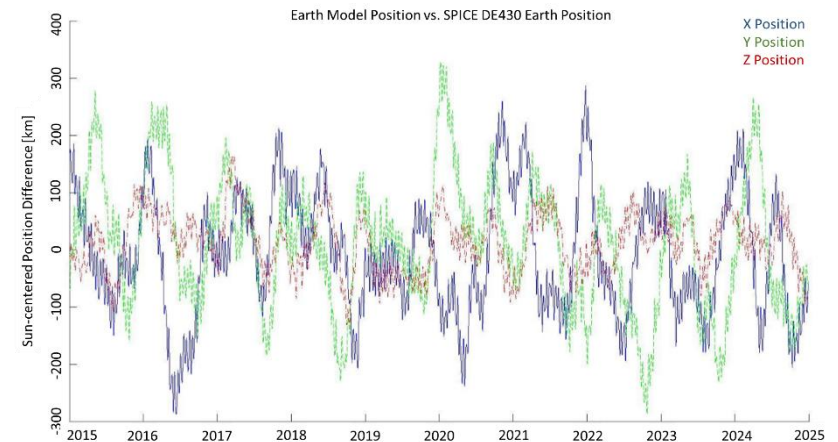
Design Challenges



- ◆ Trajectory includes three gravity-assist lunar flybys
- ◆ Lunar Orbit Insertion (LOI)
- ◆ Lunar near-rectilinear halo orbit (NRHO) – 15km perilune



- ◆ Chebyshev polynomial approach onboard ephemeris

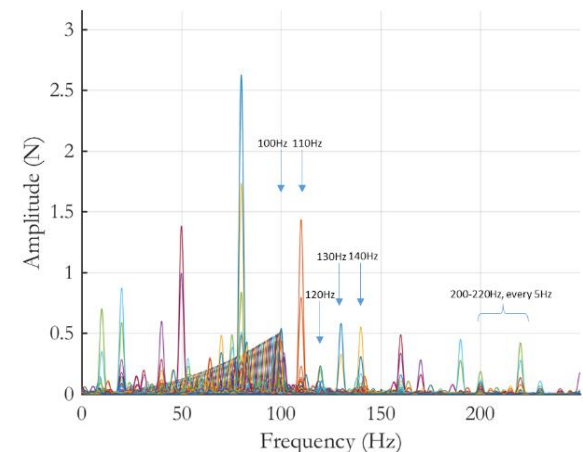
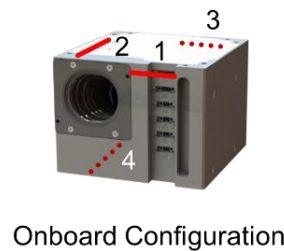
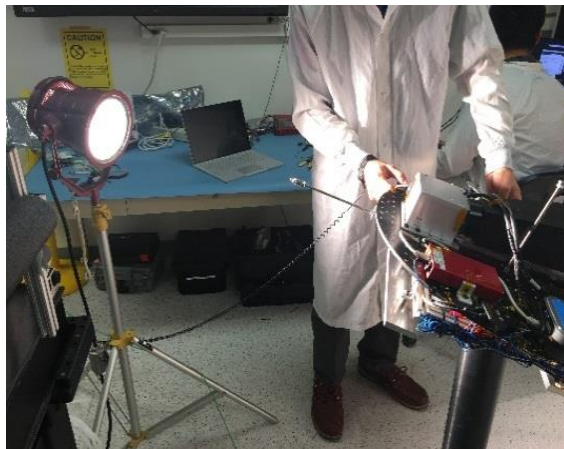
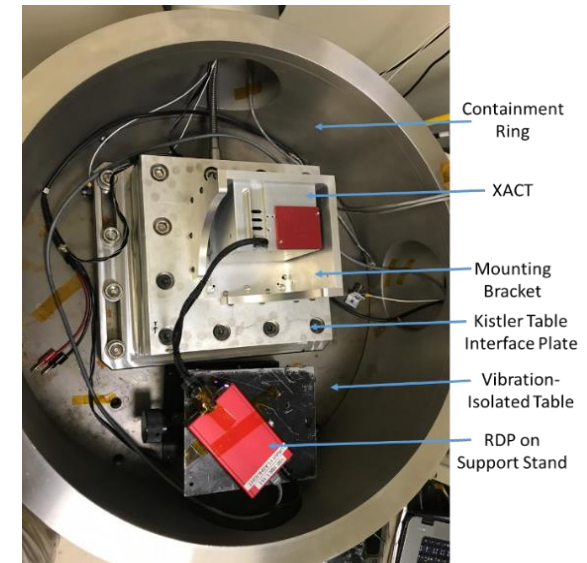
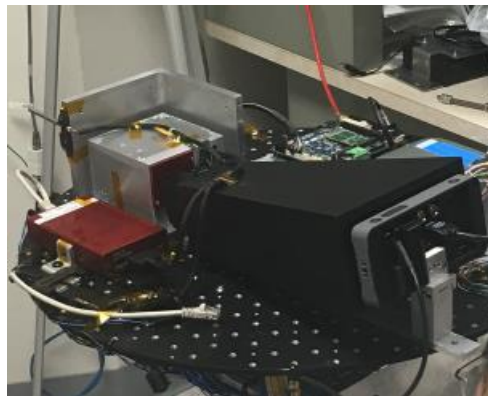
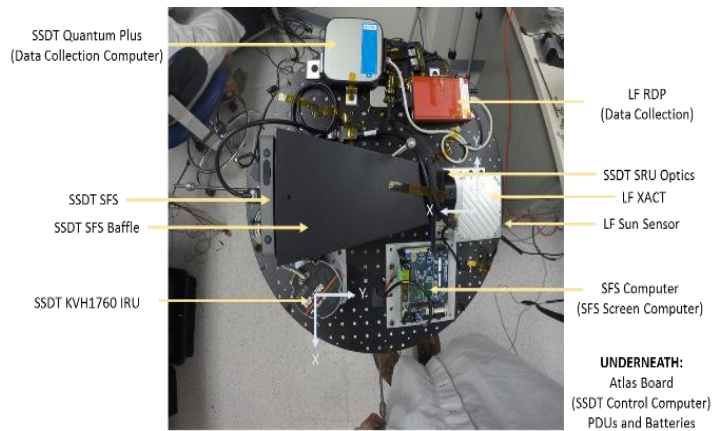




Small Satellite Dynamics Testbed (SSDT)



- ◆ RWA, Sun Sensor, IMU, SRU Phasing Tests
- ◆ Sun Point Mode & Fine Ref Point Mode Tests
- ◆ New RWA Jitter Characterization

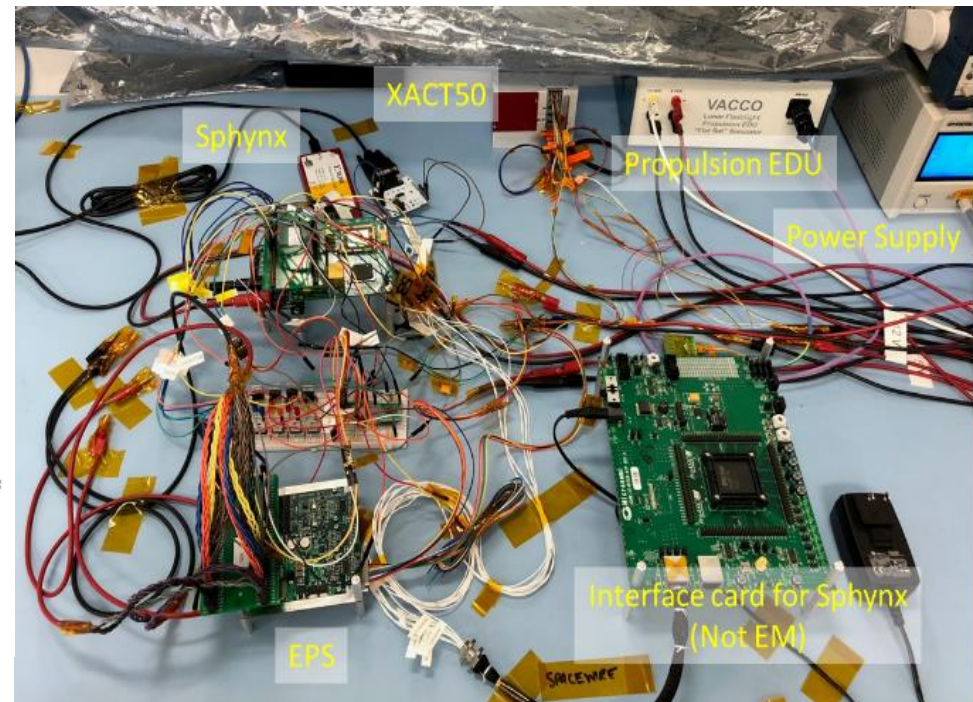
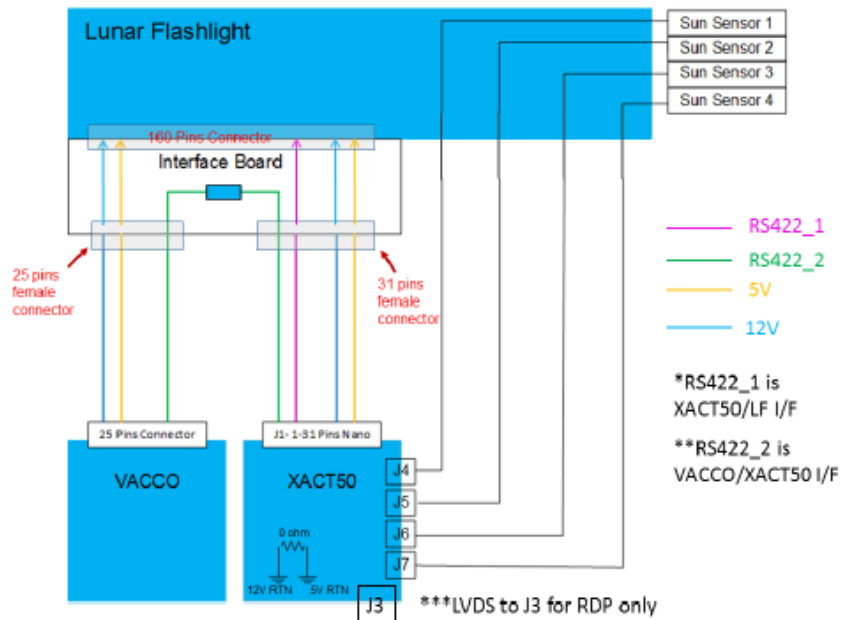




Avionic Testbed (ATB)



- ◆ Verify communication between integrated GNC system, Propulsion system, and C&DH system prior to I&T
- ◆ Crucial for early detection of any communication issue
- ◆ Used for C&DH flight software development





Lessons Learned and Summary



- ◆ **The first 6U 14 kg interplanetary spacecraft to reach and orbit the Moon and perform science**
- ◆ **Capability driven development to deliver GNC hardware and software**
 - Provide sufficient pointing and knowledge capabilities
 - Interface with other subsystems as needed
- ◆ **Technology enhancements – new RWA, green propulsion, and ephemeris/lunar orbit**
- ◆ **Sizing challenges for CubeSat:**
 - Small CM uncertainty ~5 mm is dramatic for CubeSat
 - Chemical thruster thrust and ON/OFF timing uncertainties
 - Limited amount of propellant a CubeSat can carry
- ◆ **The first CubeSat GNC system at JPL went through rigorous validation test process**
- ◆ **Integrated GNC system procurement experience**